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Recognizing Unfamiliar Faces: The Effects of Distinctiveness and View

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Three experiments are reported in which the effects of viewpoint on the recognition of distinctive and typical faces were explored. Specifically, we investigated whether generalization across views would be better for distinctive faces than for typical faces. In Experiment 1 the time to match different views of the same typical faces and the same distinctive faces was dependent on the difference between the views shown. In contrast, the accuracy and latency of correct responses on trials in which two different faces were presented were independent of viewpoint if the faces were distinctive but were view-dependent if the faces were typical. In Experiment 2 we tested participants' recognition memory for unfamiliar faces that had been studied at a single three-quarter view. Participants were presented with all face views during test. Finally, in Experiment 3, participants were tested on their recognition of unfamiliar faces that had been studied at all views. In both Experiments 2 and 3 we found an effect of distinctiveness and viewpoint but no interaction between these factors. The results are discussed in terms of a model of face representation based on inter-item similarity in which the representations are view specific.

The ability to recognize faces is essential to our everyday social interactions. For the most part we recognize familiar faces effortlessly, and changes in expression or viewpoint pose no problem. The problem of how the visual system can solve such a complex task has recently received a lot of attention (see Bruce & Humphreys, 1994). In order to recognize a face, the visual system must be able to discriminate the face from other faces whilst also allowing for changes in the image of the face with, for example, viewpoint, expression, or illumination. Thus the representation of any particular face in memory must specify the uniqueness of that face but also be versatile enough to generalize across possible changes

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in the image characteristics of that face. In particular, any model of face recognition needs to explain how different views of the same face are recognized whilst maintaining the identity of each individual face.

Recent models of object recognition propose that recognition performance across changes in viewpoint is determined by the degree of inter-stimulus similarity between the objects in the task (Edelman, 1995a, 1995b; Tarr & Bülthoff, 1995). Thus, when the objects in a task are sufficiently dissimilar, such as objects from different basic-level classes, recognition performance is found to be invariant across views (Biederman, 1987; Biederman & Gerhardstein, 1993; Newell, 1998). On the other hand, if the objects in a task are highly similar, such as objects from within the same class, recognition is found to be dependent on the view of the object (Newell, 1998; Tarr & Bülthoff, 1995). Edelman (1995a) found that by systematically increasing the similarity between objects in a classification task (and therefore reducing their discriminability), view dependency also increased. Thus the discriminability of the objects in the task can therefore affect recognition performance across changes in views.

In this paper we investigated whether faces that are more discriminable (i.e. distinctive faces) are also most easily recognized across changes in view than are faces that are less discriminable (i.e. typical faces). Recent studies have found that faces rated as distinctive or unusual are recognized more quickly than faces rated as typical or average. Distinctive faces are also less likely to be mistaken for another face than are typical faces (Cohen & Carr, 1975; Going & Read, 1974; Light, Kayra-Stuart, & Hollander, 1979; Valentine & Bruce, 1986a, 1986b). Also, Valentine and Bruce (1986a) found that faces rated as typical were more representative of the class of faces than were distinctive faces. They compared participants' classification performance of typical and distinctive faces against a set of jumbled faces. Participants had to decide as fast and as accurately as possible if each stimulus belonged to the face category or not. They found that typical faces were categorized more readily than distinctive faces.

Recently, a model of face representation in visual memory has been proposed that is based on the level of inter-item similarity between faces. This so called "face space" model has been proposed to account for the findings on the recognition of distinctive and typical faces in the literature (Johnston & Ellis, 1995; Valentine, 1991(a), 1991(b)). Specifically, this model makes predictions on the recognition of faces based on their discriminability. Like the similarity-based object recognition model proposed by Edelman (1995b), the face space model proposes that face representations in memory can be considered in terms of locations in a multi-dimensional feature space. The position of a face representation in face space reflects inter-item similarity so that similar faces will be located in closer proximity than less similar faces. Here similarity is often defined by the physical characteristics of the face (Benson & Perrett, 1994; Bruce, Burton, & Dench, 1994). The underlying principle of the face space model is that recognition performance is determined by the level of inter-item similarity between the faces: Faces that are highly similar to each other are not as readily discriminable as faces that have low inter-item similarity. The face space model has received empirical support from investigations of the effect of distinctiveness, inversion, race, and caricature on face recognition (e.g. Chiroro & Valentine, 1995; Lewis & Johnston, in press; Valentine, 1991a; Valentine & Endo, 1992).

Given the wealth of evidence in support of the ability of similarity-based models of object and face recognition to explain recognition performance, can these models account for the recognition of faces across different views? The specific question we wish to address is whether the difference in the discriminability between faces can affect recognition performance across viewpoint.

First, let us consider the effects of view change on recognition performance. A recent model of object recognition proposes that all objects are encoded as viewer-centred descriptions (see Tarr & Bülthoff, 1995). Accordingly, recognition is dependent on the distance between the image view and the stored view. Many studies have provided evidence in support of this account of object recognition (Edelman & Bülthoff, 1992; Jolicoeur, 1985; Newell & Findlay, 1997; Tarr & Pinker, 1989). More specifically, recognition performance to different views of unfamiliar faces has also been found to be dependent on the view shown (Bruce, Valentine, & Baddeley, 1987; Troje & Bülthoff, 1996). Bruce et al. (1987) reported finding view-dependent recognition performance to unfamiliar faces using a sequential matching task, although this effect was reduced for familiar faces. In a more comprehensive study of the effects of viewpoint on the recognition of unfamiliar faces, Troje and Bülthoff (1996) also found view-dependent effects. They also used a sequential matching task, but they noted that it was the learning view (the first view of the face seen) and not the test view that affected recognition performance.

Physiological studies have also provided evidence that faces are stored in a view-dependent manner. Single unit recording studies in primate cortex have found that some cells in the superior temporal sulcus are selectively tuned to viewpoint and also that some cells are selectively tuned to both the identity and the viewpoint of a face (Perrett et al., 1991; Perrett et al., 1985).

We would expect that any model of face recognition, such as the face space model, should be able to account for the recognition of different views of faces. Such a model should, therefore, have the property that different views of the same individual be integrated to allow for generalization across views. However, if we assume that recognition performance is achieved by measuring the similarity between items in representational space, then the following problem needs to be addressed: In image space two different faces from the same view are more similar to each other than are two different views of the same face.

Two ways in which this problem can be approached, within the context of a similarity-based face space model, can be identified in the literature: The representations in face space may be organized along image-based properties such as viewpoint or they may be organized by individuals. If face space was organized by viewpoint, then different views of faces would inhabit different regions of face space. This is analogous to the way different sub-spaces underlie different races of faces, as described by Valentine and Endo (1992). In this way, face space is organized according to the physical similarity between the images of each face (Benson & Perrett, 1994; Bruce et al., 1994). We assume that the location of an individual's face relative to other faces will remain invariant across the sub-spaces, for example, a distinctive face will be distinctive from all viewpoints. The separate view-specific representations of the same individual must be bound together. One possibility might be that these representations are tagged together in face space within, for example, that individual's "identity manifold" (Craw, 1995). We refer to this hypothesis as the *view-based* account, and this account is illustrated in Figure 1.

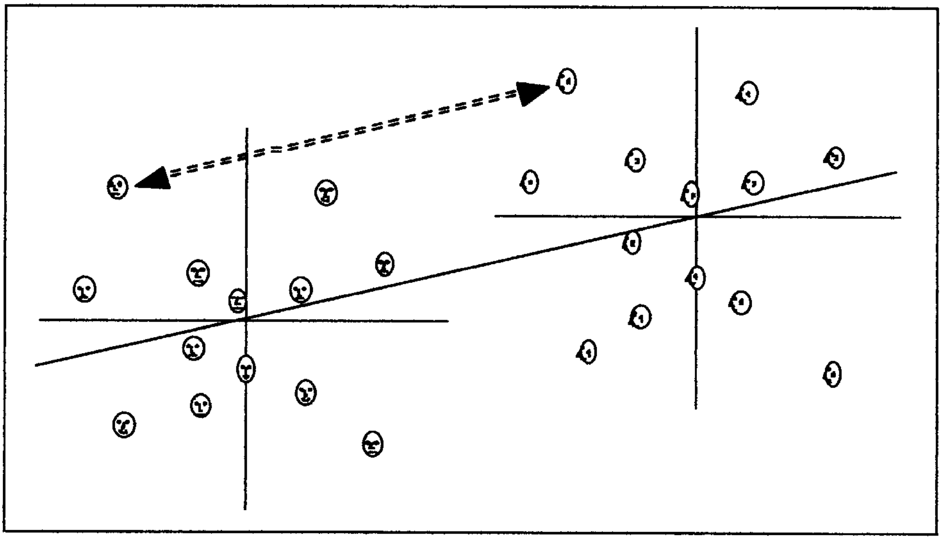

FIG. 1. A schematic illustration of the prediction made by the view-based account of the face space model. Faces are represented as view-centred descriptions on a feature space. The dimensions underlying face space are based on viewer-centred encodings such that different views of a face are located within different view-specific sub-regions of the face space. Within any single sub-region, the distance between two faces reflects the similarity between those faces. Distinctiveness is maintained across the view dimension. The arrow between two faces indicates the association between different views of the same individual. This association could occur together within an "identity manifold" or through temporal association (see text).

An alternative suggestion is that all views of faces may be located in the same face space but that different views of the same individual are located adjacent to each other in face space. Accordingly, each individual is represented by a clustering of views located together within the same face space. However, the problem here is that face space needs to encode the different views of an individual independently of their similarity to other face views. One way in which this integration process might be achieved would be as a result of temporal processing at the input stage (Wallis & Bülthoff, 1997; Wallis & Rolls, 1997). Accordingly, images that are presented in close temporal proximity are often associated as belonging to the same object or face, even when small differences in the spatial characteristics of the images occur. Recent studies have provided evidence that items presented in close temporal sequence are often associated with each other in visual memory (Miyashita, 1988; Miyashita & Chang, 1988). This approach is best illustrated by the concept of a *Face Recognition Unit* (FRU), which has been very influential in information-processing models and interactive activation models of face processing (e.g. Bruce & Young, 1986; Burton, Bruce, & Johnston, 1990). An FRU will "respond when any view of the appropriate person's face is seen" (Bruce & Young, 1986, pp. 311–312). Similarly, Valentine (1991b) assumed that each familiar face is represented within a single location in face space, implying an individual-centred representation. We refer to this hypothesis as the *individual-based* hypothesis, and this account is illustrated in Figure 2.

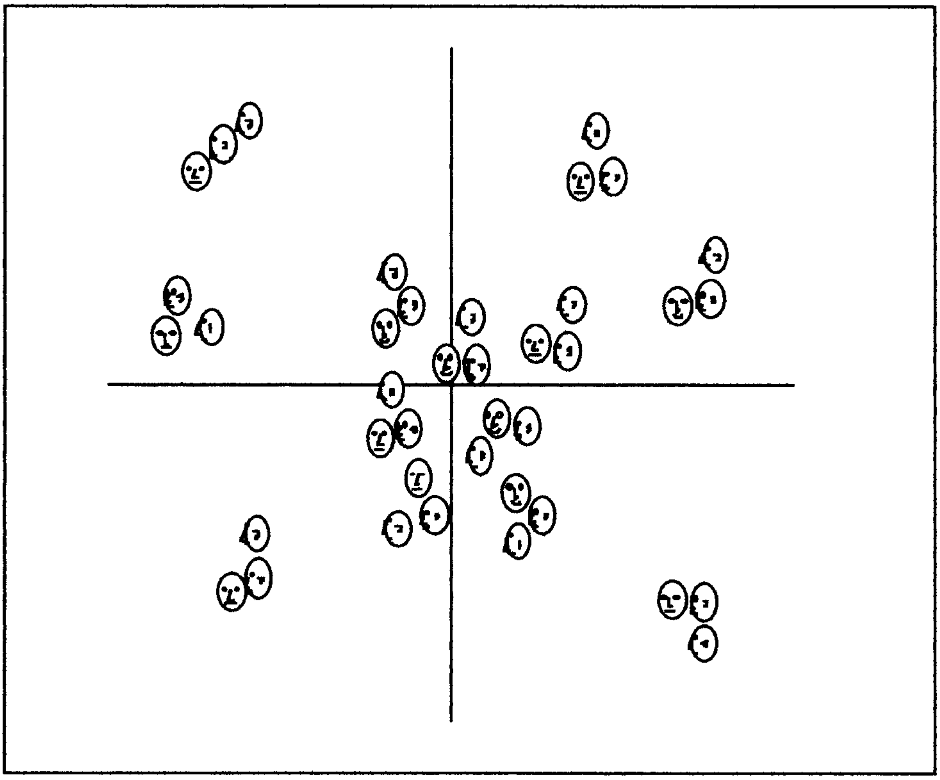

FIG. 2. A schematic illustration of the prediction made by the individual-based account of the face space model. Again, faces are encoded as view-centred descriptions on a feature space; here, however, different views of the same individual are clustered together and are encoded within the same region. A cluster of viewpoints within a single region represents a single individual. The distance between these clusters reflects the similarity between the individual faces. The two dimensions are used for illustration purposes only and are not meant to reflect any particular dimensions.

Our present experiments were based on the following empirical evidence: (a) that distinctive faces are recognized faster and more accurately than typical faces and (b) that the recognition of unfamiliar faces is dependent on viewpoint. Our empirical question was whether the discriminability of a face interacts with the recognition of that face across changes in viewpoint. We know of no previous studies of how facial distinctiveness affects recognition across different viewpoints. Similarly, there has been no analysis of relevant predictions derived from any account of face recognition based on inter-item similarity. Our aim is to explore the effects of distinctiveness and generalization across viewpoint in a number of face-processing tasks, in order to provide empirical evidence that constrains a proper conception of the structure of face memory.

The view-based and individual-based accounts make different predictions on recognition performance across views. If face space is organized as suggested by the view-based hypothesis, then the recognition performance to novel views should be the same for both distinctive and typical faces. Although recognition performance should decrease with an increasing difference in viewpoint from the familiar view, this decrease in performance should be the same for both face types because a change of viewpoint would amount to the same physical change on both face types. In contrast, if face space is organized as suggested by the individual-based account, then generalization to new views should be affected by the discriminability of that individual's face. Specifically, novel views of distinctive faces should be recognized more easily than novel views of typical faces. This is because distinctive faces, as a whole, are further from their neighbouring faces, and it would be more likely that novel views of a distinctive face would be correctly associated to the target face. The recognition of a novel view of a typical face would be poor because a new view would be encoded in a densely populated region of the face space and would therefore be less likely to be correctly associated with the target face.

Three experiments, each based on different tasks, are reported. In Experiment 1 participants had to decide whether two faces presented sequentially were of the same or a different person. This task was designed to examine the effects of a change in view on the recognition of distinctive and typical faces in a task that involved little, if any, demand on memory. This enabled us to examine the effects on perceptual processing. In Experiment 2 we investigated participants' generalization to novel views of unfamiliar faces from a learned three-quarter view of the faces as a function of facial distinctiveness in a recognition memory paradigm. This enabled us to explore the effects on face memory. In Experiment 3 recognition memory for distinctive and typical faces was investigated in a task that did not require generalization to novel views. Participants were presented with all views of the typical and distinctive faces in a learning session and were presented with the same range of views at test. This experiment allowed us to control for the possibility that distinctiveness, per se, is view dependent. Also the task is more analogous to encountering an unfamiliar person in everyday life when a range of views will be seen.

EXPERIMENT 1

This experiment was designed to investigate the effect of a change in view on the participant's speed and accuracy in deciding whether two faces shown in succession were of the same individual. The following predictions are derived from both the view-based and individual-based accounts. Both accounts make the same predictions on both the match and mismatch performance on distinctive and typical faces across views.

First we shall consider the match trials in which two images of the same person are presented in quick succession. We assume that the speed and accuracy of a match decision is determined by the distance in the face space between the two stimuli to be matched. The distance will depend on the similarity of the views to be presented. Thus, participants will be faster to match same views than different views. Both the view-based and the individual-based accounts make the same predictions for the match decisions. Specifically both accounts assume that a change of view increases the distance in face space between the representations of the two stimuli and will, therefore, make match decisions slower and less accurate. A change in angle of view should be positively related to the reaction time (RT) of match decisions and negatively related to accuracy.

As there is no—or minimal—memory component required by the task a match decision is assumed to be independent of face density in the space. Therefore, both accounts predict that there will be no effect of distinctiveness on recognition performance of match decisions. Consequently, both accounts predict no interaction between the effects of distinctiveness and a change of view for the match decisions.

We now consider predictions that can be derived for mismatch responses when views of two different faces are presented. First, the assumption that the speed and accuracy of a decision is determined by the distance in the face space between the two stimuli to be matched leads both accounts to predict that, in contrast to match decisions, there will be an effect of distinctiveness on the mismatch decisions. Two different distinctive faces will be further apart in face space than will two typical faces, therefore it will be easier to decide that two distinctive faces are different people than it will be to decide that two typical faces are different people.

The second prediction relates to the discriminability of two different faces across views. Drawing on the literature on object recognition it may be predicted that an effect of view would only be found if the faces to be matched are highly similar (Edelman, 1995a; Newell, 1998). Two different typical faces will be much more similar to each other than will two different distinctive faces. For typical faces, an effect of a difference in viewpoint would be predicted by both the view-based and individual-based accounts for the same reasons as outlined above for the match responses. In the case of two distinctive faces it may be possible to make a mismatch decision to faces that differ in viewpoint as quickly and as accurately as two faces presented in the same viewpoint. This may occur, for example, because a feature that is sufficiently invariant across the views presented does not match across the faces (e.g. one face only has very bushy eyebrows, or a distinctive skin texture). In conclusion, it is predicted that for mismatch trials only, performance will be less view dependent for distinctive faces than for typical faces.

This experiment was conducted in two parts. First, a set of sixteen unfamiliar faces were rank ordered for distinctiveness. In the second part a different group of participants carried out a face-matching task on the ranked distinctive and typical faces across different views.

DISTINCTIVENESS RANK ORDER

Method

Participants

Eighteen undergraduate students from the Department of Psychology, University of Durham were asked to rank order a set of 16 faces according to the distinctiveness of the faces. The average age of the participants was 20 years. Ten of the participants were male.

Materials

Sixteen males volunteered as models for the face stimuli and were photographed in three different poses—full face (FF), three-quarter face (TF), and profile face (PF). The models were unfamiliar to the participants in the rating study and to the participants in the subsequent experiment. Salient features such as glasses were removed before photographing. All of the images included the head and shoulders of the models, and all models were wearing similar, black clothing. The models had a neutral expression and were clean shaven. The background lighting conditions were controlled.

Each photograph was scanned into a Macintosh LC computer with a resolution of 72 dpi and a grey-scale setting of 256. The background was clipped and all the face images were matched for size. The FF view of each face was copied and arranged on a single 4 × 4 matrix. Printouts of these face matrices were distributed amongst the participants.

Procedure

Each participant was presented with a copy of all the 16 faces shown in FF view on a sheet of paper. All of the participants rank ordered the stimuli in a single session. Participants were given the following instructions:

> Imagine all of these people are in a room together. You may notice that some of the faces may be very easy to pick out in a crowd whereas others would be more difficult because some faces are a lot more distinctive than others. Which face would be easiest to pick out in the crowd?

The most distinctive face was given a score of 1 and the next most distinctive face was given a score of 2, and so on, until the most typical face was given a score of 16.

Results and Discussion

A median split was applied to the average ranked scores: Faces scoring 8 or above were grouped as distinctive faces and those below 8 were grouped as typical faces. A Kendal coefficient of concordance across participants' ranked scores proved significant, $W = 0.1026$, $\chi^2 = 29.55$, $p < .05$.

FACE-MATCHING TASK

Method

Participants

Twenty-four members of the Department of Psychology, University of Durham, participated in this experiment; 12 of the participants were male and 12 were female. The average age of the participants was 25 years. All participants had normal or corrected–to–normal vision. Participants were paid for participating in a number of different experiments during an afternoon.

Materials and Apparatus

Five different views of each individual were presented during the experiment. There were three original views of the faces (FF, TF, and PF) and in addition, both the TF and PF views were presented as mirror-reflected views yielding a total of five different views in which the face stimuli could appear—FF, TF, PF, TF–mirror (TF–m), and PF–mirror (PF–m). The stimuli were presented on a Macintosh IIx computer using SuperLab, a laboratory package for the Macintosh.

Design

The experiment was based on a two-factor, repeated measures design with distinctiveness and view as factors. The distinctiveness factor had two levels; distinctive faces and typical faces. The view factor had five levels—FF, TF, TF–m, PF, and PF–m views.

The experiment was based on a two-alternative forced-choice (2AFC) paradigm where participants had to decide if two faces shown in succession were of the same person or not. Trials were presented in pseudo-random order with the constraint that the same person was not shown in two consecutive trials. For the mismatch trials, two different faces drawn from either the distinctive face group or the typical face group, which were matched for the presence of features such as side-burns, were paired together in any one trial.

Procedure

All participants were initially presented with a practice block of eight trials. The faces used in the practice block were different from those in the experimental block.

In the experiment, the first stimulus in each trial was always shown in the FF position. The second stimulus in a trial was shown in one of the five different views. The initial stimulus was presented for 1 sec followed by an interstimulus interval (ISI) of 500 msec. A response from the participant triggered the offset of the second stimulus and the trial. Participants were instructed to respond as fast as possible to the second stimulus by pressing either the "/ " key on the keyboard if the two faces shown were of the same person or the "z" key if the faces were of different people.

Results

Response Accuracy

The percentage of correct responses was calculated for each participant for each view of the distinctive and typical faces. Separate, repeated measures, 2 × 5 analyses of variance (ANOVAs) were performed on the percentage of correct match and percentage of correct mismatch responses. Data were analysed using separate ANOVAs taking participants (F1) and items (F2) as the random factor. The factors were face distinctiveness (distinctive and typical) and view (PF–m, TF–m, FF, TF, PF). The factor of view had repeated measures in the analysis by participant and by item. Distinctiveness had repeated measures in the analysis by participants and was a between-items factor in the items analysis.

Figure 3(a) shows the mean percentage of correct responses made to the different views of the distinctiveness and typical faces in the match trials only. A 2 × 5 factor, repeated measures ANOVA on the correct hits revealed no significant effect of distinctiveness, $F_1(1, 23) = 0.924$, n.s., $F_2(1, 7) = 0.553$, n.s., an effect of view, $F_1(4, 92) = 7.976$, $p < .001$, $F_2(4, 28) = 5.325$, $p < .01$, and no interaction between the factors, $F_1(4, 92) = 0.837$, n.s., $F_2(4, 28) = 0.692$, n.s. A post hoc Newman-Keuls analysis on the effect of view revealed that the percentage of correct responses made to the profile views (PF, PF–m) was significantly lower than that to all other views ($p < .05$ by participant and by item).

Figure 3(b) shows the mean percentage range of correct mismatch responses made to the views of the different distinctive and typical faces. A 2 × 5 factor, repeated measures

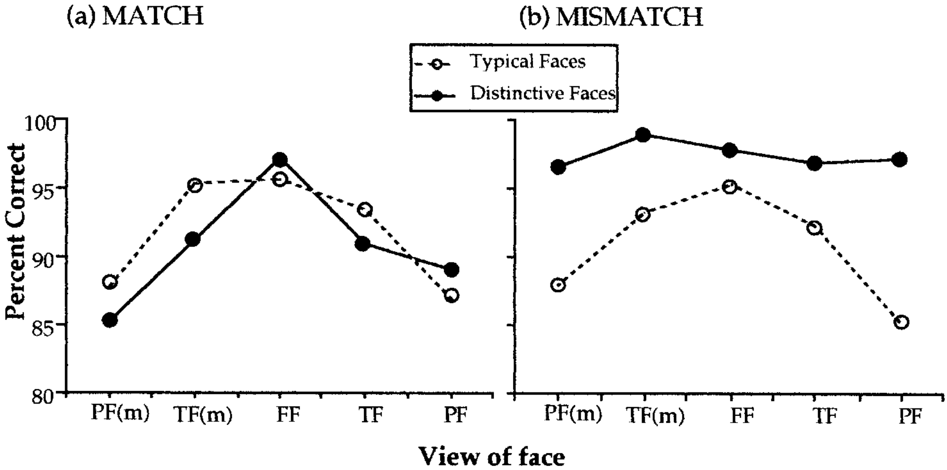

FIG. 3. Response accuracy to the different views of the distinctive and typical faces in the match trials (a) and in the mismatch trials (b) of Experiment 1. The different views of the faces are labelled PF(m) (profile face–mirror reversed), TF(m) (three-quarter face–mirror reversed), FF (full face), TF (three-quarter face), and PF (profile face).

ANOVA, taking participants as the random factor, on the correct rejections revealed a significant effect of distinctiveness, $F_1(1, 23) = 31.193$, $p < .001$, and an effect of view, $F_1(4, 92) = 5.539$, $p < .001$. An items analysis was not appropriate for the mismatch trials because each trial consisted of two items from the experimental stimuli. A post hoc Newman-Keuls analysis revealed that the percentage of correct responses to the TF and TF–m views was significantly greater than that to the profile views (PF and PF–m) at $p < .01$ level of significance. A significant interaction between the main factors was also found, $F_1(4, 92) = 3.288$, $p < .02$. Simple effects analyses revealed no significant effect of view of distinctive faces, $F_1(4, 92) = 0.931$, n.s. A significant effect of view was found for typical faces, $F_1(4, 92) = 5.406$, $p < .01$.

Reaction Times

Figure 4(a) shows the mean RTs to the correct match responses across the different views of distinctive and typical faces. A 2 × 5 factor, repeated measures ANOVA was conducted on the RTs to the correct hits. There was no significant effect of distinctiveness, F_1 (1, 23) = 2.285, n.s., $F_2(1, 7) = 1.478$, n.s. A significant effect of view was found, $F_1(4, 92) = 44.968$, $p < .001$, $F_2(4, 28) = 44.08$, $p < .001$, and there was no interaction between the factors, $F_1(4, 92) = 1.920$, n.s., $F_2(4, 28) = 1.426$, n.s. A post hoc Newman-Keuls analysis on the effect of view revealed that response times to the full-face view were significantly faster than those to all other views, $p < .01$ for participants and items.

Figure 4(b) shows the mean RTs of the correct mismatch responses to the different views of distinctive and typical faces in the mismatch trials only. A 2 × 5 factor, repeated measures ANOVA revealed significant effects of distinctiveness, $F(1, 23) = 24.867$, $p <$ .001, of view, $F(4, 92) = 5.561$, $p < .001$, and a significant interaction, $F(4, 92) = 5.285$, p

< .001. A Newman-Keuls analysis on the effect of view revealed that response times to the full-face view were faster than those to all other views at $p < .05$ level of significance. Simple effects analyses on the interaction between the distinctiveness and view factors revealed that there was no significant effect of view for the distinctive faces, F (4, 92) = 0.327, n.s., but a significant effect of view for the typical faces, F (4, 92) = 9.733, $p < .001$.

Discussion

Experiment 1 showed that participants can match two views of a typical face as readily as they can match two views of a distinctive face. Matching across two views of the same face showed strong view-dependent effects in the accuracy and latency of responses to both distinctive and typical faces. Discriminating between two different typical faces also proved to be dependent on view. However, discriminating between two different distinctive faces was independent of the view. View had no effect on the accuracy or the latency of correct mismatch decisions to distinctive faces.

These results conform to the predictions derived from a similarity-based model of face space. No effect of distinctiveness is seen for match decisions because the task has little or no memory component and so processing is independent of the density of faces in the face space. If the two faces are similar (i.e. the same face or two views of different typical faces) performance is view-dependent because it is necessary to transform one view to match the other in order to make a match or mismatch decision. In contrast, if two faces are very dissimilar they are separated by a large distance in face space and can be readily discriminated from each other despite differences in view. In conclusion, the results of Experiment 1 confirm the predictions of a model of face representation based on a

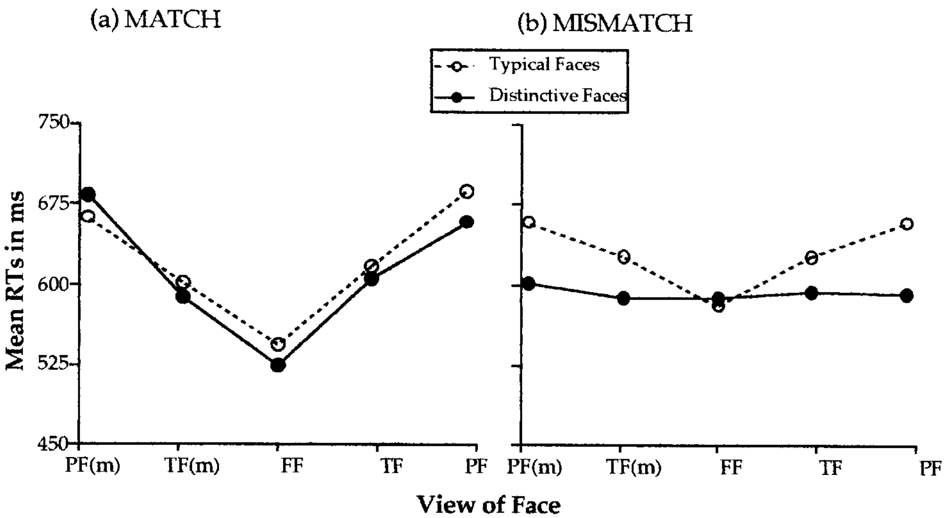

FIG. 4. Plot of mean RTs of correct responses taken to match different views of the same face (a) and different faces (b) of Experiment 1. The different views of the faces are labelled PF(m) (profile face–mirror reversed), TF(m) (three-quarter face–mirror reversed), FF (full face), TF (three-quarter face), and PF (profile face).

psychological similarity space, but they do not distinguish between a view-based and individual-based structure of representational space.

The face-matching task reported above was designed to investigate if recognition performance across distinctive and typical faces was affected by changes in viewpoint. However, a match/mismatch paradigm does not involve a substantial memory component for faces, and the results may not reflect the workings of the face representational system in memory. Indeed, distinctiveness effects have been reported mainly with recognition memory paradigms. Experiment 2 was designed to test recognition memory by initially presenting participants with a number of different faces from a single view and then testing the recognition of those faces across novel views.

EXPERIMENT 2

The following experiment used a recognition memory paradigm in order to investigate the effects of distinctiveness on the recognition of different views of faces. The view-based and the individual-based accounts make the following predictions. First, both accounts predict that distinctive faces will be recognized more accurately than will typical faces. This prediction arises because, by definition, distinctive faces are encoded in more sparsely populated areas of face space than are typical faces. Therefore, during the test phase it is easier to determine that a stimulus face matches a representation in face space because their competitor faces in memory are less similar. Second, a change in viewpoint between the learning and the test phase will impair recognition. A change in viewpoint would increase the RT because a transformation of the stimulus to match a stored representation in face space would be required.

However, the individual-based account predicts an interaction between the effects of view change and distinctiveness whereas the view-based account does not. According to the individual-based account an encoded distinctive face will be less affected by competitor faces than will typical faces. As all views of a face are located adjacent to each other then it follows that the recognition of distinctive faces should generalize across all views. Moreover, an unfamiliar distinctive face is more likely to be rejected as unfamiliar in any view than is an unfamiliar typical face. Hence, the individual-based account predicts that distinctive faces should be equally discriminable from all views but that typical faces would become less discriminable with changes in viewpoint. The findings of Experiment 1 support this model. However, the following experiment was designed as a test of representational face space because the paradigm used in Experiment 1 may not have involved the discrimination of faces in memory.

In contrast to the individual-based hypothesis, however, the view-based account predicts that changes in viewpoint would be the same for both distinctive faces and typical faces. This is because different views of faces are located in different view-specific sub-spaces of face space. Generalizing across views would involve the same transformation process into the different sub-spaces for both typical and distinctive faces. However, the distribution of the faces within each sub-space is assumed to remain intact so that distinctive faces should be more discriminable than typical faces from all views. According to the view-based hypothesis, therefore, no interaction between the distinctiveness and viewpoint of the faces was expected.

We chose the three-quarter view as the training view for consistency with the literature, because better generalization might be expected from a view that lay midway between the test views, and also because this view maximizes the salient information of the face (Bruce et al., 1987).

The following experiment was conducted in two parts. First, a number of participants were asked to rank order a set of unfamiliar faces in terms of their distinctiveness. These faces were then categorized into distinctive and typical faces for the purposes of the experiment. In the second part of the experiment, a different group of participants was presented with the faces shown from the three-quarter view only in a training session. They were subsequently tested on the recognition memory for these faces across all the test views.

DISTINCTIVENESS RANK ORDER

Method

Participants

Forty members of the Department of Psychology, University of Durham volunteered to participate in this study (28 females and 12 males). The average age of the participants was 27 years. None of the participants had participated in the matching task in Experiment 1.

Materials

The stimulus set consisted of monochrome prints (approx. 35×40 mm) of 48 male faces. All of the models were unfamiliar to the participants. The face stimuli were different to the faces used in Experiment 1. They formed a larger set of faces photographed under controlled conditions. The stimulus set was divided into two different categories of 24 faces—targets and distractors. The targets were matched with distractors for incidents of features such as side-burns, lightness of hair, hairstyles, and combinations of these features, in order to avoid the possibility of participants using coincidental local features to recognize the faces. All models were photographed from the shoulders up and were all wearing similar black clothing. The models had a neutral expression and were clean shaven, and none wore glasses or any other accessories. Only the full-face view was shown to the participants. Each photograph was scanned into a Macintosh LC computer. The background was clipped, and the faces were controlled for size and lighting conditions. The faces were copied and arranged onto one of two 6×4 face matrices; one matrix consisted of the target faces and the other of the distractor faces. Printouts of these matrices were distributed to the participants.

Procedure

Half of the participants were asked to rank order the 24 target faces, and the other half were asked to order the distractor faces. Participants were not informed whether the face set would consist of targets or distractors. The face sets were ranked separately because of the large number of stimuli used. Each participant group received the same instructions on how to rank order the faces. The same instructions used in Experiment 1 were given to the participants except that the maximum score given was 24 and not 16.

Results and Discussion

The mean ranked score was calculated for each unfamiliar face. A median split was conducted on the mean ranks, and the two sets of faces (targets and matched distractors) were divided into equal groups of 12 typical and 12 distinctive faces. The inter-participant reliability was measured using Kendal's coefficient of concordance, which proved significant for both the target face set, $W = 0.299$, $\chi^2 = 143.24$, $p < .001$, and the distractor face set $W = 0.286$, $\chi^2 = 118.468$, $p < .001$.

RECOGNITION MEMORY TEST

Method

Participants

Eighteen undergraduate students from the University of Durham participated in this experiment. Nine of the participants were female. The average age of the participants was 23 years. All participants had normal or corrected–to–normal vision. Participants were paid for participating in a number of experiments in an afternoon. None of the participants participated in the previous experiment or in the rank-order study of this experiment.

Materials and Apparatus

Three different views—full face (FF), three-quarter face (TF), and profile face (PF)—of the rank-ordered distinctive and typical target and distractors were used as stimuli. The experiment was run using a Macintosh LC computer with a resolution of 72 dpi and a grey scale setting of 256. SuperLab software was used to present the stimuli and record the responses. The typical and distinctive faces were divided into two experimental blocks. Each block consisted of a learning session followed by a test session. During the learning sessions of the experiment, each target face was presented to the participant from the three-quarter view only. Each face remained on the computer screen for 3 sec. During the test session participants were presented with the target faces from all three views—the FF view, the TF view, and the PF view. Matched distractor faces were also presented at all three experimental views during the test sessions.

Design

The experiment was based on a two-factor, repeated measures design with face distinctiveness and face view as factors. There were two levels to the face distinctiveness factor—distinctive faces and typical faces. There were three levels to the face view factor—full face (FF), three-quarter face (TF), and profile face (PF). The experimental procedure was based on a recognition memory design in which participants initially learned the target faces and were then tested on their recognition of those faces in a separate test session. The experiment was run as separate blocks of distinctive and typical faces. Each block consisted of a learning session followed by a test session. The order of the blocks was counter-balanced across participants.

Procedure

During the learning session of each experimental block, participants were presented with 12 target faces in random order and were instructed to study each face in order to recognize it in the following test session. Participants saw each target face from the three-quarter view, and after the face was presented they were instructed to press the space bar to continue to the next face. During the learning session each target face remained on the screen for 3 sec.

The test session followed the learning session after an average delay of about 1 min while the subjects read the instructions for the test. During the test session participants were presented with the 12 target faces from all three views—the FF view, the TF view, and the PF view. Twelve matched distractor faces were also presented across all three views in the test session. The trials were presented in random order across participants. There were 72 trials in each test phase. A short practice block of six randomly chosen trials preceded the experimental block in order to introduce the participants to the task. Each face stimulus was preceded by a central fixation cross which remained on the screen for 500 msec. Participants were instructed to fixate the cross before the onset of each stimulus and to respond to each face view as fast as possible without making unnecessary mistakes. Participants were required to press the "/ " key if the stimulus was a face shown during the learning session and the "z" key if the face was not shown in the learning session. A participant's response triggered the offset of each face stimulus. Participant's RTs and errors were recorded.

Results

Table 1 shows the mean percentage hits and correct rejections given to the different views of the distinctive and typical faces. The A′ scores were calculated on the mean hits and correct rejections for each of the participants. We used A′, rather than hit and false positive rates, because A′ is a criterion-free measure of subjects' sensitivity in discriminating between faces. Figure 5 shows participants' mean A′ scores to the distinctive and typical faces across the different views. A 2 × 3 factor, repeated measures ANOVA, taking participants as the random factor, was conducted on the A′ scores. A significant effect of distinctiveness was found, $F_1(1, 17) = 11.11$, $p < .01$. Distinctive faces were recognized more accurately than were typical faces. A significant effect of view was also found, $F_1(2, 34) = 3.993$, $p < .05$. There was no significant interaction between the factors,

TABLE 1
Means of Participants' Percentage of Hits and Correct Rejections to the Views of Faces in Experiment 2

	Distinctive Faces			*Typical Faces*		
	Full Face	*Three-quarter Face*	*Profile*	*Full Face*	*Three-quarter Face*	*Profile*
Hits	77.7 (4.8)	66.2 (4.0)	67.1 (4.0)	69.9 (4.6)	61.1 (5.0)	63.4 (5.0)
Correct rejections	65.3 (4.3)	84.7 (3.6)	72.7 (5.0)	56.0 (4.0)	76.8 (4.3)	66.7 (3.8)

Note: Standard errors of the mean shown in parentheses.

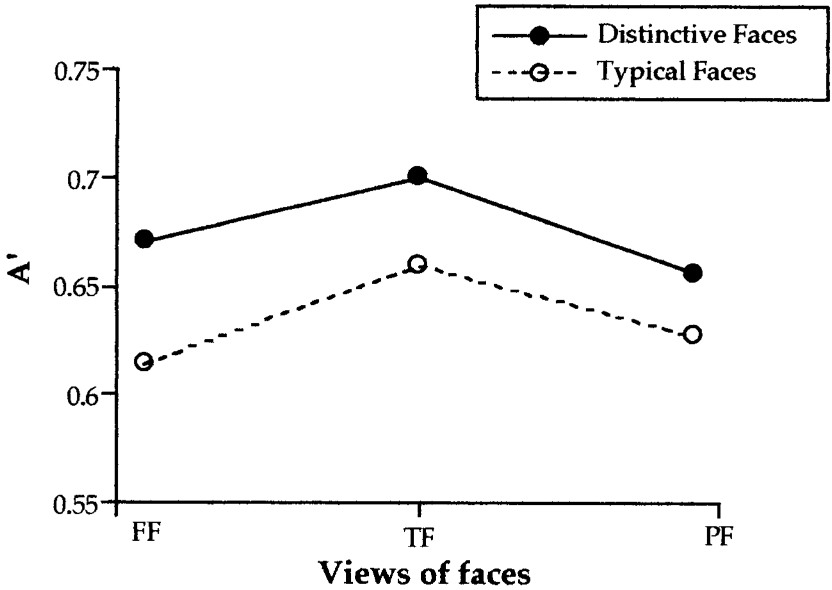

FIG. 5. Plot showing participants' mean A′ scores to the distinctive and typical target faces across the three different views in Experiment 2. Participants were trained on the three-quarter view prior to test.

$F_1(2, 34) = 0.7255$, n.s. An items analysis was not appropriate here because data from both targets and distractors are used to calculate A′. A post hoc Newman-Keuls analysis on the effect of view revealed that responses to the three-quarter view were significantly more accurate than responses to the full-face or profile views at $p < .05$ level of significance.

Figure 6 shows the participants' mean RTs to the hits (a) and correct rejections (b) on the distinctive and typical faces across the three different views.

Separate 2 × 3 way, repeated measures ANOVAs were conducted on the mean RTs to the hits and correct rejections. For the RTs to the hits, there was no significant effect of face distinctiveness, $F_1(1, 17) = 1.717$, n.s., $F_2(1, 11) = 2.398$, n.s. A significant effect of view was found, $F_1(2, 34) = 7.172$, $p < .01$, $F_2(2, 22) = 22.230$, $p < .001$. There was no significant interaction between the factors, $F_1(2, 34) = 0.1434$, n.s., $F_2(2, 22) = 0.619$, n.s. A post hoc Newman-Keuls analysis on the effect of view revealed that the response times to the full-face view were significantly slower than those to either the three-quarter or the profile view, $p < .01$ for both participants and items.

For the RTs to the correct rejections, there was no effect of distinctiveness, $F_1(1, 17) = 0.015$, n.s., $F_2(1, 11) = 0.168$, n.s. There was a significant effect of view, $F_1(2, 34) = 5.632$, $p < .01$, $F_2(2, 22) = 24.943$, $p < .001$. No significant interaction between the factors was found, $F_1(2, 34) = 1.239$, n.s., $F_2(2, 22) = 1.235$, n.s. A post hoc Newman-Keuls analysis on the effect of view revealed that response times to the profile views were significantly faster than those to the three-quarter or full-face views, $p < .05$ for participants and $p < .01$ for items. Distractor faces were, therefore, rejected more quickly at the profile view.

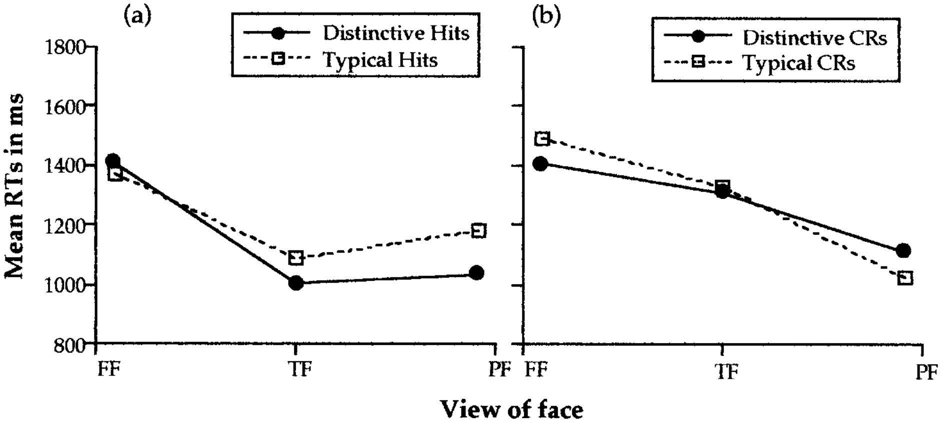

FIG. 6. Plot of the mean response times to the hits (a) and correct rejections (b) across the different views of the distinctive and typical faces in Experiment 2.

Discussion

Distinctive faces were recognized more accurately than were typical faces. This effect is consistent with an inter-item similarity model of face representation. However, there was no effect of distinctiveness on the RT of hits or correct rejections. Although it was expected that the RT measures would show an effect of distinctiveness, there are two reasons why an effect may not have emerged in these data. First, the accuracy of response was approximately 77%. This is well short of the ceiling. Reaction time data would be expected to reflect an effect of distinctiveness more reliably when the recognition accuracy is high. As the response data were derived from the correct responses only, the relatively low accuracy means that A′ may be the more reliable dependent variable. Second, the literature shows that the effect of distinctiveness is seen more reliably in false positives than in hits (e.g. Valentine, 1991b). This tendency can be seen in Experiment 2 (Table 1). As false positives are errors, the RT of false positives have not been analysed.

For both face types the recognition of full-face views was slower than the recognition of profile views. These effects are predicted by an inter-item similarity representation of faces. The most interesting aspect of the data is that there is no interaction between the effects of distinctiveness and a change of view. The individual-based account predicts that a change of view should have less effect on the recognition of distinctive faces than on the recognition of typical faces. The results of Experiment 2 are inconsistent with this hypothesis. On the other hand, the view-based account is consistent with the lack of an interaction because the same transformation used to match a novel view with a familiar view would be performed regardless of whether the face was distinctive or typical.

For both face types there was a large disruption of recognition performance on the response times to the full-face view. One suggestion for this finding is that there is perhaps more image-feature mapping between the three-quarter views and the profile views than between the three-quarter views and the full-face views. For example, many features that participants may use to discriminate between the faces at the three-quarter view, such as eye-brow protrusion or size of nose, are foreshortened in the full-face views. These features can still be used to discriminate between the faces at the profile view because the feature information remains intact under such a transformation. Therefore, the three-quarter view and the profile view may be more similar in psychological face space than the three-quarter and the full-face view, thus perhaps contributing to the increase in response times to the full-face view.

EXPERIMENT 3

In Experiment 3, recognition memory for distinctive and typical faces was investigated in a task that did not require generalization to unseen views. Participants were presented with three views of the faces during learning. The views were presented in rapid succession and appeared like a moving sequence of a face. Recognition of the faces from each of the views was tested subsequently. This experiment was designed to investigate the effects of distinctiveness and of viewpoint in a task that is more representative of encountering an unfamiliar person in everyday life when a range of viewpoints will be seen. Also in this experiment we tried to control for the possibility that distinctiveness, per se, is vulnerable to changes in viewpoint. For example, a long nose may make a face distinctive from both a profile and a three-quarter view, but this information is not available in the full-face view and therefore the face may not be considered distinctive from that view.

An inter-item similarity model of face recognition predicts that distinctive faces will be recognized more accurately and more quickly than typical faces. Unlike Experiment 1 the task in the present experiment has a considerable memory load; therefore, exemplar density at the location in which a face is encoded will affect recognition performance, giving rise to the better recognition of distinctive faces. There is no factor of a change of view in this experiment because the faces were presented in all views tested. Nevertheless the view presented at test may affect performance to the extent that there may be a "canonical" view of faces from which they may be more easily recognized than from other views. This effect, however, is not accounted for within a model-based on inter-item similarity. Therefore, there is no a priori reason from this theoretical framework to expect any effect of view to interact with the effect of distinctiveness.

Palmer, Rosch, and Chase (1981) found that certain canonical views of objects were rated as "better", and the objects depicted in these views were named faster. Bruce et al. (1987) suggested that a three-quarter view is a canonical view of a face. They found faster matching of three-quarter views of unfamiliar faces than of either full-face or profile views in a sequential matching task. However, they found equivalent performance from full-face and three-quarter views of familiar faces in a matching task and in a recognition task. Profile views were slower to be recognized than either full-face or three-quarter views of both familiar and unfamiliar faces in a matching task. Bruce et al. (1987) concluded that a three-quarter view may reveal more information on which matching can be based, but they found no evidence that a three-quarter view is a canonical representation for familiar faces.

Troje and Bülthoff (1996) also found view-dependent effects using a sequential matching task, but they noted that it was the learning view (the first view of the face seen) and not the test view that affected recognition performance. They argued that the canonical view is closer to the full-face view than to the three-quarter view. Although response times were not reported, Troje and Bülthoff 's data indicate that generalization from a learned three-quarter face to the full face resulted in approximately 10% more errors than the generalization from the full face to a three quarter face (see Figure 5 in Troje & Bülthoff, 1996). They also found that profile views yielded the poorest match performance. On the basis of this literature, we predicted that recognition of profile views would be more difficult than the recognition of either full-face or three-quarter views. No clear prediction of a difference in recognition of unfamiliar faces from three-quarter or full-face views can be made.

Method

Participants

Eighteen members of the Department of Psychology, University of Durham participated in this experiment. The average age of the participants was 25 years. All participants had normal or corrected–to–normal vision. Participants were paid for participating in a series of experiments during an afternoon. None of the participants participated in the previous experiment or in the rank-order study of the previous experiment.

Materials and Apparatus

Three different views—full face (FF), three-quarter face (TF), and profile face (PF)—of the rank-ordered distinctive and typical target and distractors were used as stimuli. The experiment was run using a Macintosh LC computer. SuperLab software was used to present the stimuli and record the responses.

Design

The experiment was based on a two-factor, repeated measures design with face distinctiveness and face view as factors. There were two levels to the face distinctiveness factor—distinctive faces and typical faces. There were three levels to the face view factor—FF, TF, and PF.

The experimental procedure was based on a recognition memory design. The experiment was run as separate blocks of distinctive and typical faces. Each block contained a learning session and a test session. The order of the blocks was counter-balanced across participants. In each learning session 12 target faces were presented in a random order across participants. During the test session each target face was tested in each of the three views shown in the learning session. Matched distractor faces were also presented across all three views in the test session. The trials were presented in random order across participants. There were 144 trials in the experiment.

Procedure

During the learning session of each experimental block, participants were presented with the target faces and were instructed to study each face in order to recognize it in the following test session. Participants saw each target face from three different views—full face, three-quarter face, and profile face—and after the face was presented they were instructed to press the space bar to continue to the next face. The three different views of each target face were presented in rapid succession on the computer screen. This rapid change of view gave the impression of movement, so that participants perceived each individual model turn its head from full-face to three-quarter view to profile and back again. Each face was shown rotating through the views for 3 sec, with 1 sec for each view (i.e. during the motion sequence the full-face and three-quarter views were presented twice for 500 msec, and the profile view was shown once for 1 sec, thus ensuring equal exposure of all views). During the test session single views of the target and distractor faces were presented in a random order across participants.

In the test session, each face-view stimulus was preceded by a central fixation cross, which remained on the screen for 500 msec. Participants were instructed to fixate the cross before the onset of each stimulus and to respond to each face view as fast as possible without making unnecessary mistakes. Participants were required to press tne "/ " key on the computer keyboard if the stimulus was a face shown during the learning session and the "z" key if the face was not shown in the learning session. A participant's response triggered the offset of each face stimulus. Participants' RTs and errors were recorded.

Results

Table 2 shows the mean percentage of hits and correct rejections given to the different views of the distinctive and typical faces. The A′ scores were calculated on the mean hits and correct rejections for each of the participants. Figure 7 shows participants' mean A′ scores to the distinctive and typical faces across the different views. A 2 × 3 factor, repeated measures ANOVA was conducted on the A′ scores. There was a significant effect of distinctiveness, $F(1, 17) = 7.329$, $p < .02$ (distinctive faces were recognized more accurately than were typical faces), and a significant effect of view, $F(2, 34) = 11.712$, $p < .001$. There was no significant interaction between the main factors, $F(2, 34) = 0.298$, n.s. A Newman-Keuls analysis on the effect of view revealed that recognition accuracy was more impaired to the profile views than all other views at $p < .05$ level of significance.

Figure 8 shows the participants' mean RTs to the hits (a) and correct rejections (b) on the distinctive and typical faces across the three different views.

TABLE 2
Means of Participants' Percentage of Hits and Correct Rejections to the Views of Faces in Experiment 3

	Distinctive Faces			*Typical Faces*		
	Full Face	*Three-quarter Face*	*Profile*	*Full Face*	*Three-quarter Face*	*Profile*
Hits	87.0 (2.2)	77.3 (3.9)	71.3 (4.3)	74.1 (4.9)	69.9 (5.0)	66.7 (4.8)
Correct rejections	86.6 (3.1)	83.3 (3.4)	80.1 (4.3)	79.6 (5.1)	79.2 (4.1)	72.2 (3.7)

Note: Standard errors of the mean shown in parentheses.

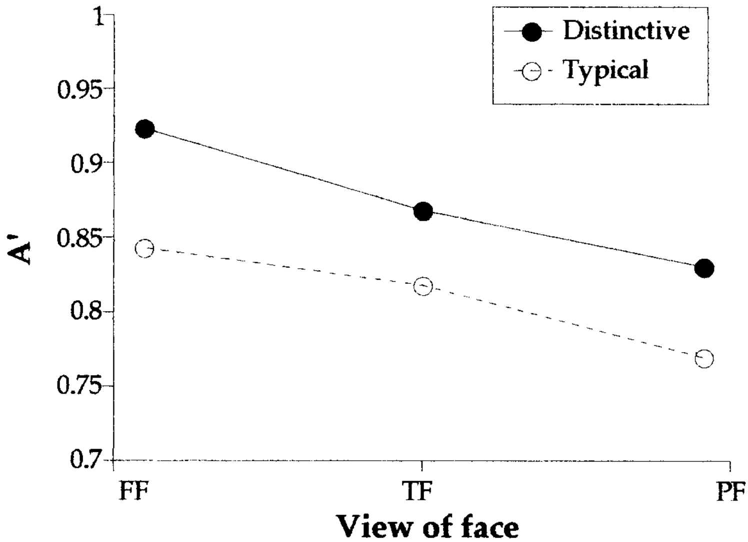

FIG. 7. Plot showing participants' mean A′ scores to the distinctive and typical target faces across the three different views in Experiment 3. Participants were trained on all views prior to test.

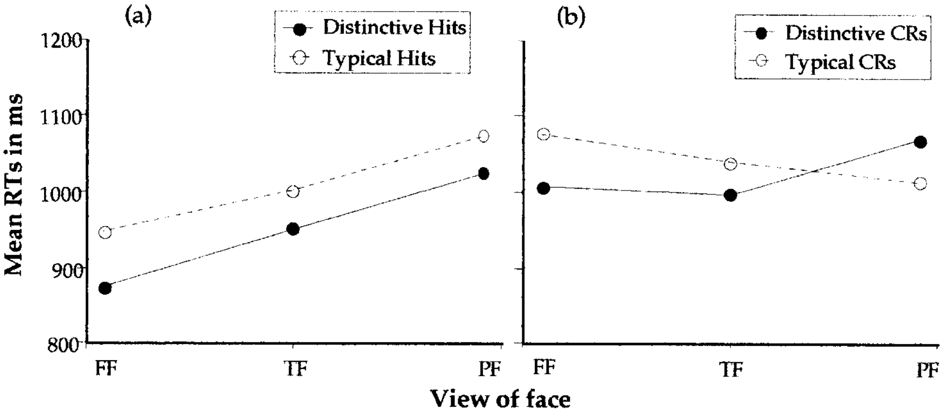

FIG. 8. Plot of the mean response times to the hits (a) and correct rejections (b) across the different views of the distinctive and typical faces in Experiment 3.

Separate 2 × 3 repeated measures ANOVAs, taking participants as the random factor, were conducted on the mean RTs to the hits and correct rejections. In similar analyses by items, distinctiveness was a between-items factor. For the RTs to the hits, there was no significant effect of face distinctiveness, $F_1(1, 17) = 2.485$, n.s., $F_2(1, 11) = 3.079$, n.s. A significant effect of view was found, $F_1(2, 34) = 16.966$, $p < .001$. $F_2(2, 22) = 12.4$, $p < .001$. There was no significant interaction between the factors, $F_1(2, 34) = 0.062$, n.s., $F_2(2, 22) = 0.344$, n.s. A post hoc Newman-Keuls analysis on the view effect revealed that response times were significantly faster to the full-face view than to either the three-quarter or the profile view, $p < .01$ for participants and $p < .05$ for items. The response times to the profile view were slower than those to the three-quarter view, $p < .05$ for participants and for items.

For the RTs to the correct rejections, there was no effect of distinctiveness, $F_1(1, 17) = 0.457$, n.s., $F_2(1, 11) = 0.211$, n.s. There was no effect of view, $F_1(2, 34) = 0.516$, n.s., $F_2(2, 22) = 0.171$, n.s., and no significant interaction between the factors, $F_1(2, 34) = 1.496$, n.s., $F_2(2, 22) = 0.756$, n.s.

Discussion

Overall, distinctive faces were recognized more accurately than were typical faces. However, the RTs of hits and correct rejections to distinctive faces were not faster than RTs to typical faces. These results are similar to those found for Experiment 2, and the comments made above also apply to these data. The effect of distinctiveness on accuracy conforms to the predictions made by similarity-based models of representational space (Edelman, 1995a; Valentine, 1991a).

A significant interaction between distinctiveness and view was not found with either the RT data or the A′ data. However, for both distinctive and typical faces the view presented at test produced an effect on accuracy of recognition and on the latency of hits. Profiles were less accurately recognized than the other views. Hits made to profile views were slower than hits made to three-quarter views, which were slower than hits made to full-face views. There was no difference in the accuracy of responses to three-quarter views and full-face views. These data are equivocal in the debate of whether a three-quarter view or a full-face view provides the canonical representation for recognition of unfamiliar faces. What can be concluded from this experiment and the extant literature is that there is a clear disadvantage for recognition of profile views and that there is probably little to choose between three-quarter and full-face views.

There was no effect of view found in the time to correctly reject the unfamiliar, distinctive faces or unfamiliar, typical faces. The finding that the time to reject unfamiliar, distinctive faces was invariant to viewpoint was not surprising given that the comparison between the distractor face and a target face can occur without recourse to any transformation process that aligns views because all views of the target faces were available for direct comparison. However, because all views of the target faces were stored, then by the same argument, a direct match between a view of a perceived target face and the same view of the stored target face might also have been applied, which would have resulted in view-independent results. Instead view-dependent effects were found to the target faces. This finding could occur for two reasons. First, a canonical view would promote faster recognition times (Bruce et al., 1987; Palmer et al., 1981; Troje & Bülthoff, 1996). Second, a confirmatory process may occur that would align a less informative view (such as profile view) to a more canonical (or salient) view of the face (Ullman, 1989), even after the face was identified (Corballis, 1988).

GENERAL DISCUSSION

The results of the experiments reported can be summarized as follows: A change in the view of a face that is seen makes recognition slower and more difficult in both a matching (Experiment 1) and a recognition memory task (Experiment 2). When all three views of a previously unfamiliar face have been seen, the recognition of three-quarter and full-face views was faster and more accurate than the recognition of profile views. Full-face views were recognized faster but not more accurately than three-quarter views (Experiment 3). It is easier to recognize a distinctive face than it is to recognize a typical face (Experiments 2 and 3), but two views of a distinctive face were not easier to match than were two views of a typical face (Experiment 1). The only case of view-independent processing observed was for correct mismatch decisions to two different distinctive faces. Correct match decisions to all faces and correct mismatch decisions to typical faces in a matching task, and recognition memory of all faces were found to be view-dependent. The effect of view on correct match decisions and on recognition memory decisions was equivalent for typical and distinctive faces.

The effects of distinctiveness on recognition accuracy are consistent with inter-item similarity models of representation (e.g. Edelman, 1995a; Valentine, 1991b). When the task involves memory for faces, distinctive faces are recognized more accurately than typical faces because there is less competition from nearby faces represented in the similarity space. Matching two sequentially presented faces, which requires a single face to be remembered for a very brief period, is not affected by the density of representations in the space because no comparison to other faces in memory is necessary.

We investigated whether the discriminability of a face affected the recognition of different views of that face. Recent models of object and face recognition appeal to the notion of inter-item similarity as a predictor of recognition performance across views. In general, items that are less similar should be recognized more easily across changes in viewpoint than items that are highly similar (Edelman, 1995a; Newell, 1998). We proposed two ways in which an inter-item similarity model of face representation could incorporate recognition from different viewpoints. It was suggested that representations in the similarity space may either be view based (there being a separate, view-specific region of face space for each view of an individual, and different views of the same person are somehow tagged together across these regions) or individual based (there being a cluster of views, lying adjacent to each other, representing all views of that individual in face space). Experiment 2 provided a basis on which to decide whether a view-based or an individual-based account should be preferred. These experiments are broadly consistent with a generic account based on inter-item similarity model and are also consistent with the view-based representations identified.

The individual-based account makes a clear prediction that the recognition accuracy of distinctive faces should be less view dependent than the recognition of typical faces. This prediction is analogous to the effects of inversion on recognition of distinctive and typical faces observed by Valentine (1991b). However, Experiment 2 clearly demonstrated that there is no interaction between the effects of distinctiveness and generalization to a novel view on recognition memory for faces. Instead, our findings lend support to the view-based hypothesis. A possible account for the view-dependent effects observed is that a face is transformed from an unseen (or a less informative) viewpoint to a familiar (or more salient) representation. However, the recognition process per se is more accurate for distinctive faces because of the effect of face density in the space.

The difference between the effect of view on distinctiveness across different faces in a matching task and in a recognition memory task may simply reflect the task demands. For example, a recognition memory paradigm involves the discrimination of a face from all other faces in memory (or at least all other target faces in memory), thus rendering the task more difficult than comparing two different faces. Thus matching across two different faces, as in Experiment 1, can occur directly without comparison to other faces in memory. However, the similarity between the two faces will affect this matching performance. Two different typical faces are more similar to each other than are two different distinctive faces. Therefore, two different typical faces cannot easily be rejected as different faces until some transformation process aligns the faces for comparison. On the other hand, two distinctive faces may be easily rejected because they are more likely to be discriminable on some feature that is independent of viewpoint. This rejection process may occur so rapidly that any effects of viewpoint (which would normally be observed) would be obscured. As the number of distinctive faces increases in a task (as in the recognition memory tasks) then so does the number of discriminable features. In this case the task may again be difficult, with the result that the distinctive faces are aligned to the nearest view of the targets for comparison.

In conclusion, we found that the discriminability of a face had no differential effect on generalizing across different views of that face. The experiments reported provide empirical constraints on any successful model of face matching performance and recognition memory for unfamiliar faces. The results are consistent with a model of faces represented in a psychological similarity space. The data from our experiments of recognition memory for unfamiliar faces across viewpoints are more compatible with a model of representational face space in which the structure of face space is based on view-centred encodings. If the location of faces in representational face space is determined by their physical similarity (Benson & Perrett, 1994; Bruce et al., 1994) then it is feasible to assume that the underlying dimensions of face space are based on viewer-centred encodings, as was proposed by our view-based hypothesis. This is because the images of faces shown from the same view are physically more similar than faces shown from different viewpoints. Different views of an individual may be integrated across face space, for example, in an individual's manifold. Craw (1995) recently proposed a manifold model of face and object representation in which different views of face lie on an identity manifold in a multi-dimensional similarity space. The results reported here are consistent with this model.

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